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The Bat Hat

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Dedication

This graduation project is dedicated to our parents, who sacrificed and exerted the utmost efforts to be what we are now, they taught us that the best kind of knowledge to have is that which is learned for its own sake and learned us that even the largest task can be accomplished if it is done one step at a time.

Acknowledgements

Dr. Kamel Saleh has been the ideal graduation project supervisor. His sage advice, insightful criticisms, and patient encouragement aided the writing of this report in innumerable ways. I would also like to thank our well-respected doctors who steadfast support of this project was greatly needed and deeply appreciated.

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Abstract

For this final project, the ultrasonic range-finding Bat Hat that uses haptic feedback to alert its wearer about obstacles in his or her path has been designed and implemented. The Bat hat is equipped with an ultrasonic transmitter/receiver circuit, which is capable of emitting short pulses of ultrasonic-frequency (approximately 40 kHz) sound. These pulses echo off the closest object in the line of sight of the ultrasonic sensor and are picked up by the receiver. The time delay between sending the initial pulse and receiving the echo gives a sense of how far away the obstacle is from the ultrasonic sensor, which can be conveyed to the person by vibrating disk motor at a level proportional to that distance. This allows the person to understand what obstacles are in his or her path and to respond accordingly.

Specifically, this project is intended as a proof-of-concept/prototype for a product that would ultimately be used by sight-impaired individuals to detect walls or other obstructions. This device is considered clever implementation of using inaudible frequencies which simulate using a cane to feel the obstacles. In addition to that, this device has the ability to work in tough environments like noisy, rainy and windy ones.

The Bat Hat is divided into two main wearable sub-systems: a head-mounted navigation sub-system and a hand-mounted tactile sensor sub-system. The head-mounted navigation device is used for spatial sensing and directional navigation, while the hand-mounted tactile sensor is used for sensing obstacles in close proximity to the user below eye-level.

Chapter 1

Introduction

Chapter 1: Introduction

1.1 Overview

This device uses ultrasonic rangefinders and haptic feedback to improve indoor navigation for the visually impaired people and to help people seeing at night. The technique depends on using acoustic signals, such as sounds from the natural environment or sounds made artificially, to determine an individual's surrounding physical space for the purpose of navigation. This device is a clever implementation of using this technique that uses inaudible frequencies which simulate using a cane to feel the obstacles. In addition to that, this device works in noisy environment where it is typically difficult to sense acoustic signals.

The Bat Hat consists of two main parts, the first one is the well-designed head mounted navigation that consists of three ultrasonic range finders, Arduino UNO and three vibrating motors to help the user to turn either left or right depending on the presence of obstacles in the field range of the ultrasonic sensors, while the other ingenious part is the wearable tactile which consists of one ultrasonic range finder, Arduino NANO and one motor that simulates the traditional cane to scan the obstacles not detectable by the mounted navigation .

1.2 Existing Problems

Globally, an estimated 285 million people were estimated to be visually impaired, 39 million were blind and 246 have low vision **[1].** In addition to that, about 90% of the world's visually impaired live in low-income settings **[1].** As a result, this fact forms the motivation to build a clever, small device to help them with a cost considered too cheap related to its valuable function.

Additionally, Normal people cannot walk at night with the absence of light and if they do, they will expose themselves to hazards because walking at night is uncomfortable and difficult to detect the obstacles that surround you, so that this device will give you directions to be in safe and sound and help many people in their daily life.

1.3 Aims And Objectives

Mainly, this technology aims to provide a better life to people by either increasing the awareness of people about the objects that surround them in the absence of light or by enabling people who have visual or auditory impairments to live independently without needing any help from any one.

Besides that, this device contributes in reducing the accidents that the visually impaired or blind people are exposed to, and increases the self-confidence to that group to join the life normally and independently. As a result, the productivity of that group will obviously increase.

1.4 Scope Of The Work

1.4.1 General Overview

The Bat Hat is comprised of two main wearable sub-systems: A head-mounted navigation sub-system and a hand-mounted tactile sensor sub-system (see Figure 1.4.1.1 for a high-level overview). The head-mounted navigation device is used for spatial sensing and directional navigation, while the hand-mounted tactile sensor is used for sensing obstacles in close proximity to the user below eye-level, similar to the traditional "Hoover" cane.

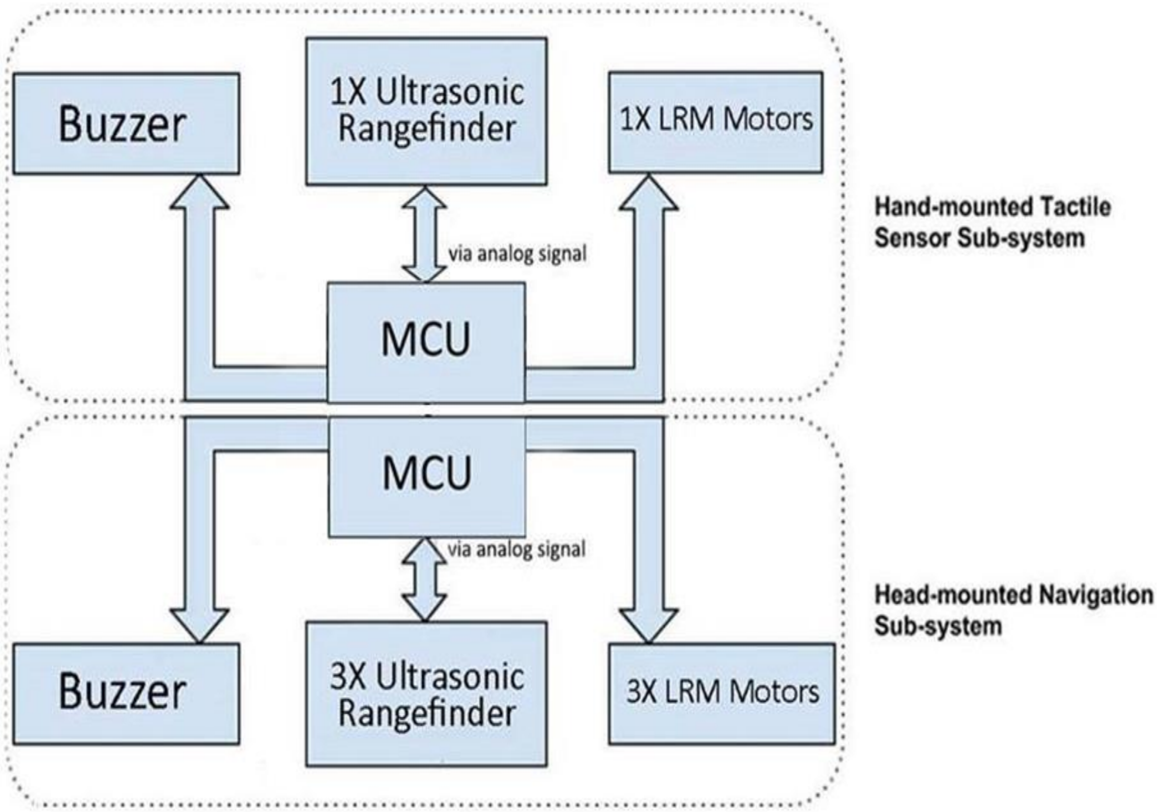

Figure 1.4.1.1: Shows High Level Overview

The head-mounted navigation system consists of three ultrasonic rangefinders, Arduino UNO and three vibrating motor discs in addition to the buzzer that will send warning signal when the object is very close to the user to increase the awareness. The rangefinders are capable of detecting obstacles up to 4 meters away with a field of view of about 15degrees **[2].** The head-mounted system instructs the user to turn left, right or even indicates if there is something in front of the user using one of the three motors mounted on the three sides of the user's head.

The hand-mounted tactile sensor consists of one ultrasonic rangefinder, Arduino NANO and one motor that the user can wear on his or her hand. The tactile sensor allows the user to "scan" for obstacles below eye-level (typically out of the range of the head-mounted sensors) by sweeping his or her hand laterally, similar to how one would use an assistive cane. The rate at which the motors pulse is proportional to the distance of the obstacle from the user -- the closer the object, the more rapid the pulses.

1.4.2 Distance Calculation

The ultrasonic rangefinder works by emitting an ultrasonic pulse and timing the duration it takes to receive the pulse reflected off an obstacle. As the speed of sound in air is approximately 340m/s (disregarding variations in humidity, pressure, interference, etc.), the distance of the obstacle can be determined by (340 * (measured duration))/2.

The previous equation determines the distance of an object by using the duration time which is the difference between the trigger signal and received signal, it best described as follows:

$$\textbf{Distance} = \frac{\textbf{Duration time}[\textbf{us}] * \mathbf{0.034}[\frac{\textbf{cm}}{\textbf{us}}]}{\mathbf{2}} = \mathbf{0.017} * \textbf{Duration time}\ \ [\textbf{cm}]$$

Equation 1.4.2.1: Distance Equation.

Where, distances in [cm] and duration time in [μs] as Arduino assumes.

1.4.3 Hardware Overview

Arduino microcontrollers were used because they are easy to program, cheap to buy and perfect for prototyping device.

Prototyping ultrasonic rangefinders were used to reduce the cost and to ease the programming, but in future work commercial ultrasonic rangefinders with a large range and a wide beam pattern can be used, the large range ensures that obstacles can be detected far away and the wide beam pattern gives us a greater field of view.

A fourth ultrasonic rangefinder was mounted on the hand tilted towards the ground to detect objects below eye-level and sudden changes in elevation, which could be indicative of a flight of stairs.

Ultrasound was used as opposed to infrared for ranging, since ultrasonic characteristics are best suited for this device. This device requires larger ranges than most infrared transmitter/sensor setup can detect, and was designed mainly for use in indoor environments where interference from other infrared-emitting sources can pose a problem.

Mini-vibrating motor was used because this shaft-less vibratory motor is perfect for non-audible indicators, it shakes crazily and softly but noticeably. Moreover, Buzzer was used to increase the awareness of the user when the object is very close to him/her.

The two sub-systems work integrally and separately without any connecting wire between them.

1.4.4 Software Overview

This device uses the real time to provide real-time functionality, this allows the device to perform certain tasks simultaneously, such as allowing the user to use the extended tactile sensor independently of the head-mounted navigation system.

There are real-time tasks for the sequential reading of each ultrasonic rangefinder and two other separate tasks for the navigation logic, one for instructing the user to either turn left or right, and another for the tactile sensor.

The problem of overlapping between each two sensor was solved by using special loop in the program and by directing each sensor to separate direction.

All the readings are median filtered so as to remove discrete noises caused by interference (typically from external sources) or noises in the sensor circuit.

1.5 Importance Of The Work

The importance of this work is summarized in offering a hat and small tactile that eases the daily life of people, especially to those who have disability to get around and understand their surrounding easily by feeding them with indicators which tell them to turn left, right or even if there is anything in their way. Consequently, that will increase the ability to that group to join life with high self-confidence, and also it will increase their capacity in all levels.

CHAPTER 2

Constraints, Standards And Earlier Coursework

Chapter 2: Constraints, Standards And Earlier Coursework

2.1 Constraints

In every project constraints must be shown through every stage of the project starting from choosing the title to delivering the report. In this project the first constraint was the essence of the work either by determining the goal behind it, choosing the boundaries of this project or deciding the target group, but all of that are decided after two or three discussions between us and the supervisor. The second one was the cost of the elements is equal to 600 NIS at Nablus which is high according to a prototype, so that it is decided to buy the elements online that made the cost much lower (100 NIS instead of 600 NIS). The Third one is related to the arrival of the components to test them and understanding their attitudes, this is solved initially by installing the datasheet for each element and using Proteus as a simulation program that helped us to get all the results.

In addition to that, one of the main problems was dealing with the educational ultrasonic rangefinder sensor because most of the time was giving us an accurate results, at the end the problem is solved through adding special codes and controlling the angle of each one in the hardware design.

2.2 Standards

Mainly, the IEEE Code of Ethics is always relevant. Being a relatively-long term project, it is always a good idea to be aware of the safety of others, good social conduct, and honesty **[3]**.Moreover, there are several international standards associated with sounds and their relationships with human beings. One major standard is ISO 532:1975, “Acoustics -- Method for calculating loudness level," which "Specifies two methods for determining a single numerical value of a given sound, the first method is based on physical measurements, the second method is based on spectrum. Analyses in one-third octave bands **[4]**."ISO 28961:2012, "Acoustics -- Statistical distribution of hearing thresholds of ontologically normal persons in the age range from 18 years to 25 years under free-field listening conditions **[5]**, " shows that we are operating well outside of the human hearing range, which is related to ISO 266:1997, "Acoustics -- Preferred frequencies**[6]**." Lastly, because of the haptic component of the project, ISO standard 9241-920:2009, “Ergonomics of human-system interaction -- Guidance on tactile and haptic interactions,” "gives recommendations for tactile and haptic hardware and software interactions **[7]**.

2.3 Earlier coursework

Through the five years too many courses are taken, some of them have been used in this project in direct way or not directly either in hardware design, software design, writing the report or even in preparing the presentation. The following paragraphs mention the courses that used in this project.

English 102, Principles of Scientific Research and Technical Writing, English in Workspace contents were employed in writing professional report and preparing a perfect presentation.

C++ and Microcontroller are employed in programming the Arduino, understanding the concept of the microcontroller and how can be used.

Electrical circuits 1, 2 and Electronics Circuits 1, 2, 3 helped us to understand the usage of different electrical components and guided us to install these components correctly.

Sensors and Measurements helped us to deal with different sensors, such like the ultrasonic rangefinder, and got us the basic knowledge to use each sensor correctly.

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CHAPTER 3

Literature Review

Chapter 3: Literature Review

The inspiration of this project came from the way that bats use to understand their surrounding and how they can avoid collisions with obstacles by using the echolocation. Echolocation animals emit calls out to the environment and listen to the echoes of those calls that return from various objects in the environment. They use these echoes to locate, range, and identify the objects. Echolocation is used for navigation and for foraging (or hunting) in various environments **[8].** However, that principle could help humans with guidance and navigation as well, especially humans who are blind and have difficulty in understanding their surroundings using “normal” senses.

There have been similar head-mounted assistive devices developed in the past, such as Sonic-guide, (developed around 1974) by Leslie Kay who has improved the angular resolution of his Binaural Sensory Aid (BSA) system using a third narrow beam transmitter for creating an additional monaural signal. This newer system was first called the Trisensor, but is now known as the KASPA system (Kay's Advanced Spatial Perception Aid). KASPA represents object distance by pitch, but also represents surface texture through timbre. Use is made of echo location through frequency-modulated (FM) signals. The improved, but still modest, resolution probably positions Kay's work somewhere between obstacle detection and environmental imaging. The best angular resolution is about one degree in the horizontal plane (azimuth detection) for the central beam, which is quite good, but vertical resolution (elevation) is poor - making the ``view'' somewhat similar to constrained vision with binocular viewing through a narrow horizontal slit**[9]**. Whatever, those devices were inaccurate enough and they used Complex methods to navigate.

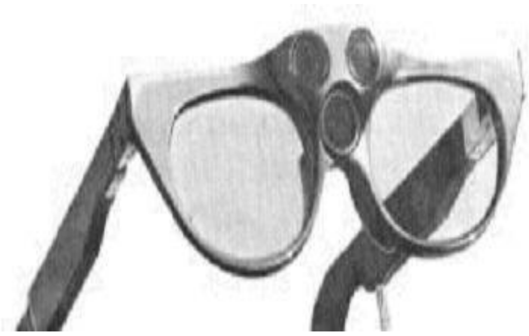

Figure 3.1: Shows Sonic Guide [9]

Figure 3.2: Shows KASPA [9]

Additionally, there have been some similar modern designs that have the same goal, but different techniques and concepts. First, Mayur Patel have designed DOPPLER RADAR FOR COLLISION AVOIDANCE that uses Doppler radar sensors in order to provide the user with movement, speed, and distance information of their environment. An array of Doppler radar sensors are placed on the users head and vibration motors are placed on the user’s chest, neck, back, and/or arms in order to provide input to the user without impeding any of their other senses. When something moves within about 25 feet of the user, the corresponding vibration motor for the particular direction relative to the user where the movement was detected will activate with a certain intensity to indicate how far away the movement was detected **[10],** while in this project ultrasonic sensors are used instead of Doppler radar, Arduino instead of AVR and totally different techniques were applied to approach the goal. Second, JulianoSilotoAssine and Murilo Augusto Gallani have designed Ultrasonic pathfinder that consists of a wearable device to provide aid for the visually impaired. An ultrasonic distance sensor located on a hat collects data of the surrounding environment scanning the area ahead of the user, and uses this data to give an audio feedback through stereo headphones. Using the principles of human sound localization this feedback provides information on the location and distance of the obstacles around the user by changing the angle and intensity of the sound produced **[11]**, while in the used design one Arduino is enough instead of two Atmega128 and all the procedures were totally different.

Moreover, there are two patents are figured out that are relevant to this project. The first one is US20120299643, "Driving circuit for a circuit generating an ultrasonic pulse, in particular an ultra-sonic transducer, and corresponding driving method," which is related to the subject matter of this project **[12]**. However, the approach that is used in the design was very different from that in the patent. Another applicable patent is WO2012123787, “An echolocation apparatus,” which, according to the Abstract, “comprises an echolocation module configured to determine a distance to the object based on the received sound signal reflected from an object.” This patent is not as relevant to this project, but does contain interesting ideas related to ultrasonic range-finding **[13]**.

However, many of these past devices have several deficiencies of this device, such as limited field of view and noisy sensor outputs leading to incorrect feedback. Furthermore, none of the previous projects has elements that could detect obstacles that are most hazardous to a visually impaired person, obstacles below the eye-level that could probably cause the visually impaired person to collide and fall.

As such, the Bat Hat is an improved device that combines various aspects of past projects that worked well in a more cohesive and ergonomic package with a cost considered the lowest among all the previous devices. On top of that, the device is extended with an addition tactile sensor that allows the user to detect low-lying obstacles in an intuitive and familiar manner by mimicking the use of a “Hoover” cane. It is also decided to use haptic feedback to interfere with the hearing of the user because visually impaired people are typically more depending on their sense of hearing in navigating the physical space. Haptic feedback would also allow this device to be used in noisy environments.

CHAPTER 4

Methodology

Chapter 4: Methodology

4.1 Hardware Design

4.1.1 Schematic

4.1.1.1 Head-Mounted Navigation Sub-System Schematic

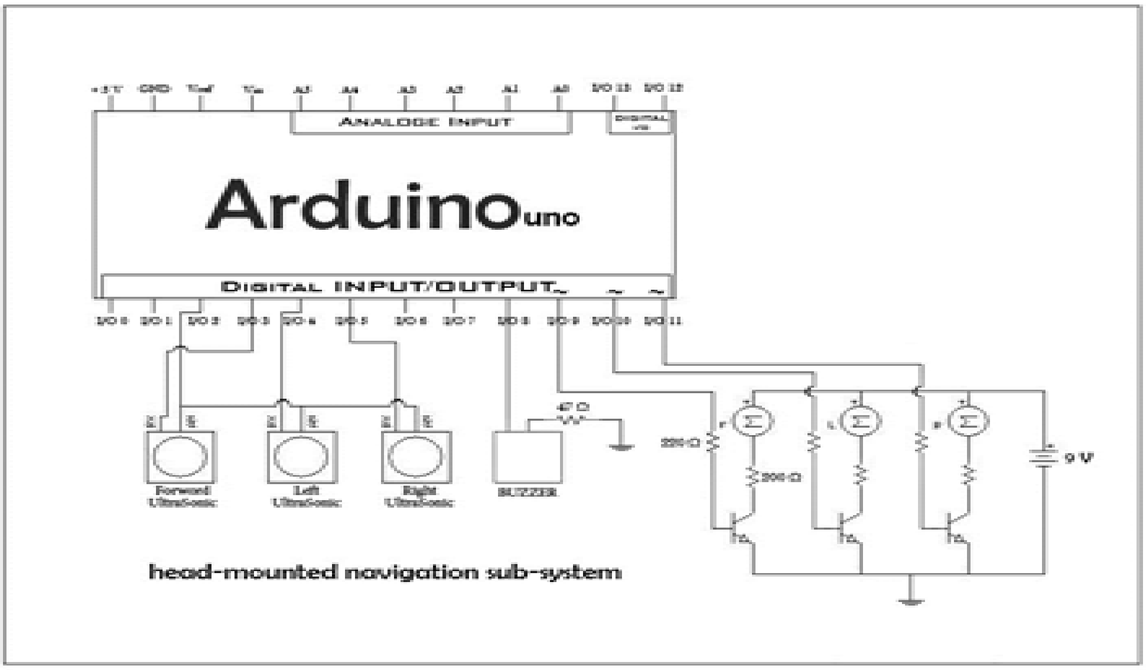

Figure 4.1.1.1.1: Shows the Schematic of Head-Mounted Sub-System

4.1.1.2 Hand-Mounted Tactile Sensor Sub-System Schematic

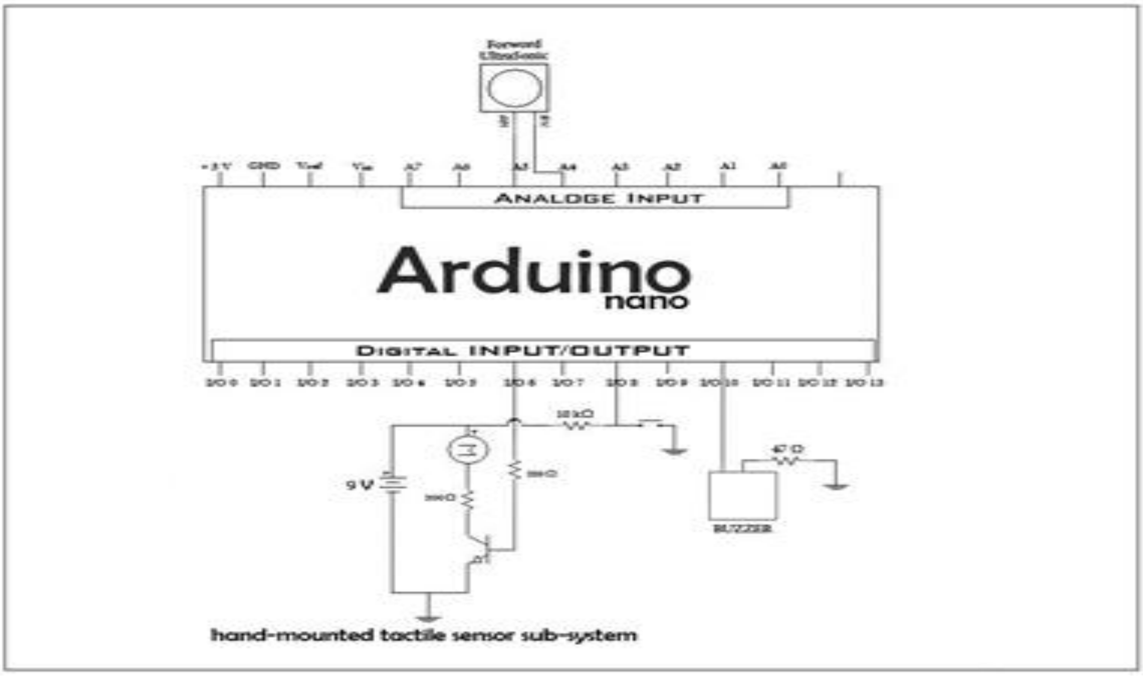

Figure 4.1.1.2.1: Shows the Schematic of Hand-Mounted Tactile Sub-System

4.1.2 Microcontroller

Arduino Uno has been used in the head-mounted navigation sub-system, this Arduino uses Atmega328. Initially, it is wanted to use the ATmega1284 to get more accurate results, but after studying the Arduino Uno it is found that it's accurate, easy to deal with and suitable for this project.

The Arduino Uno (see figure 4.1.2.1) is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started **[14]**.

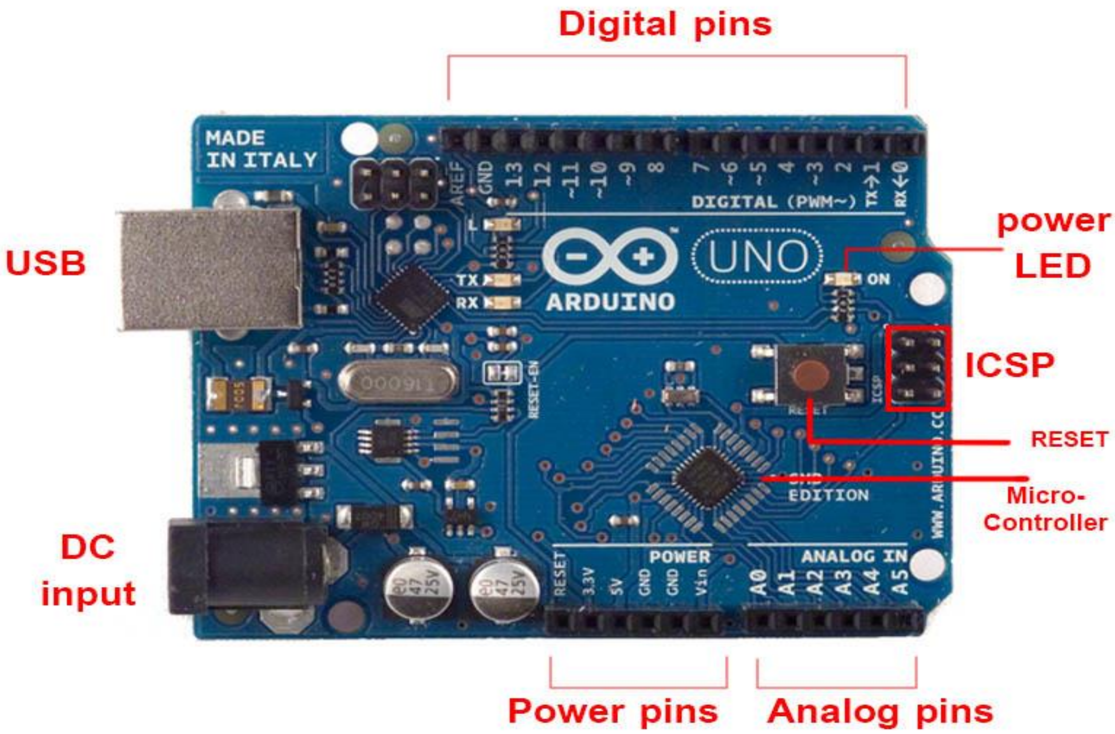

Figure 4.1.2.1: Shows Arduino Uno [14]

Arduino Nano has been used in hand-mounted tactile sensor sub-system to get stylish view because it is too small with Length of 45mm, width of 18mm and weight of 5g, this Arduino uses Atmega328. It is wanted to use two FM circuits to communicate with the two sub-systems, but the Nano was the choice because it is cheaper and does not need any connected wire between the two sub-systems. Arduino Nano is a small, complete, and breadboard-friendly board. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.

The Arduino Nano (see figure 4.1.2.2) is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 8 analog inputs, a 16 MHz crystal oscillator, a USB connection button. It contains everything needed to support the microcontroller. Simply, the Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), o

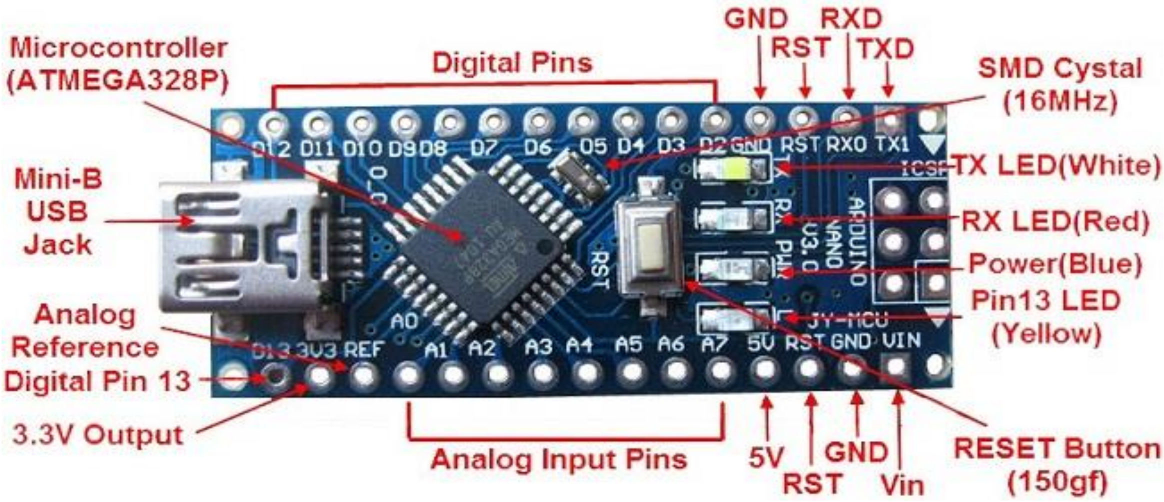

Figure 4.1.2.2: Shows Arduino Nano [15]

4.1.3 Motor

The motors that have been used are vibrating mini disc motors. These motors are small disc-shaped motors that are adhered to the head-hat and the hand-strap of the device.

The motors operate when driven between 3V to 5V, with a 60mA current draw at 3V and a 100mA current draw at 5V **[16]**

Figure 4.1.3.1: Shows Vibrating Motors [16]

It is decided to drive the motors directly from the 9V battery via a simple control circuit through the use of 2N3904 NPN BJTs. It is found that even though motors could drive by pulses at 5V from the Arduino's pins, it is concerned that driving the motors for extended durations of time would draw too much current (peak current of ~100mA) from the Arduino and would cause the on-board voltage regulator to reset the MCU because the maximum allowable current from each pin is 40mA as mentioned in the datasheet.

The control circuit uses a control signal from Arduino output pin into the base of the BJT, with the emitter connected to ground and the collector connected to the negative terminal of the motor. The positive end of the motor is driven from a potential divider circuit that provides it with 4.5V.

4.1.4 Buzzer

Buzzer has been used as an additive warning signal to increase the awareness of the user in order to stop or changing the path to avoid dangers. It will be activated when the user is in real danger.

4.1.5 Ultrasonic Rangefinder

The ultrasonic rangefinders that have been used are the HC-SR04 Ultrasonic Rangefinders Four of these rangefinders have been used, with three mounted on the head-mounted navigation system and one has been used for the hand-mounted tactile sensor.

Figure 4.1.5.1: Shows HC-SR04 Ultrasonic Rangefinders [17]

The HC-SR04 sensor has a maximum operating range of 4m and a beam width equal to 15 **[16]** which is considered not wide enough so that three sensors are used in order to cover as wide a field-of-view as possible.

The four sensors are powered with 5V to get as much range and as wide a beam pattern as possible, and the ranging of the sensors is controlled through control signals from four output pins from the Arduino into the RX pin of the sensor.

The Timing diagram figure 4.1.5.2 is shown below. The trigger input need only to be supplied by a short 10uSpulse to start the ranging, and then the module will send outran 8 cycle burst of ultrasound at 40 kHz and raise its echo. The Echo is distance object that is pulse width and the range in proportion .The range will be calculated through the time interval between sending trigger signal and receiving echo signal. Formula: the range = high level time * velocity (340M/S) / 2 **[17]**.

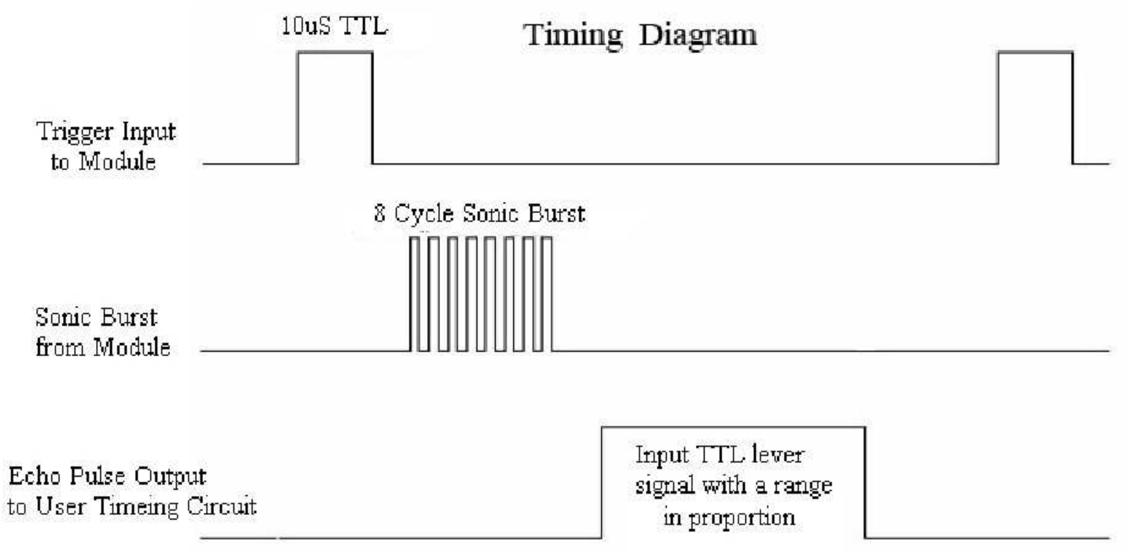

Figure 4.1.5.2: Shows The Timing diagram [18]

4.1.6 Power

The Arduinos and the motors are powered using tow 9V batteries with tow 9V battery holders. It is tested that two 9V batteries are sufficient in powering this device.

4.2 Software Design

4.2.1 Head-Mounted Navigation Sub-System

4.2.1.1 Initialization

First of all, a library labeled as newping is called that exists in Arduino which is responsible for preparing and running the HC-SR04 Ultrasonic Rangefinders. The mentioned library contains definitions of all needed variables that will be used in main functions includes the number of sensors which is 3 in this Sub-System, maximum distance in cm for each one that equals 500cm for each sensor, the delay between each sensor to avoid cross-sensor echo 33milliseconds are chosen according to the equation below (See equation 4.2.1.1.1), to guarantee that there is no intersection between two echoes and two arrays the first one holds the times when the next trigger should happen for each sensor, while the second array stores the distance measured for each sensor to check it later by a function to determine the warning signal if the value within the dangerous region. In addition to that, each sensor is defined by three values which are the trigger pin, the echo received pin and the maximum distance.

As mentioned in distance calculation, the equation below determines the distance in [cm], according to datasheet or the HC-SR04 ultrasonic rangefinder the maximum distance can be read by it is 500cm, now if this value is substituted in that equation, it can be found that Duration time equals to 29milliseconds:

$$\textbf{distance} = \frac{\textbf{duration time}[\textbf{us}] * \textbf{0.034}[\frac{\textbf{cm}}{\textbf{us}}]}{\textbf{2}} = \textbf{0.017} * \textbf{duration time} \ [\textbf{cm}]$$

$$\Rightarrow \ \textbf{duration time} = \frac{\textbf{2*500}}{\textbf{0.034}} = \textbf{29411}[\mu\textbf{s}] = \textbf{29.4}[\textbf{ms}]$$

Equation 4.2.1.1.1: Shows the Duration time Equation.

4 milliseconds are added for safety factor to have a 33milliseconds for each sensor to make sure that no intersection can be happened between at least two sensors.

4.2.1.2 Flowchart

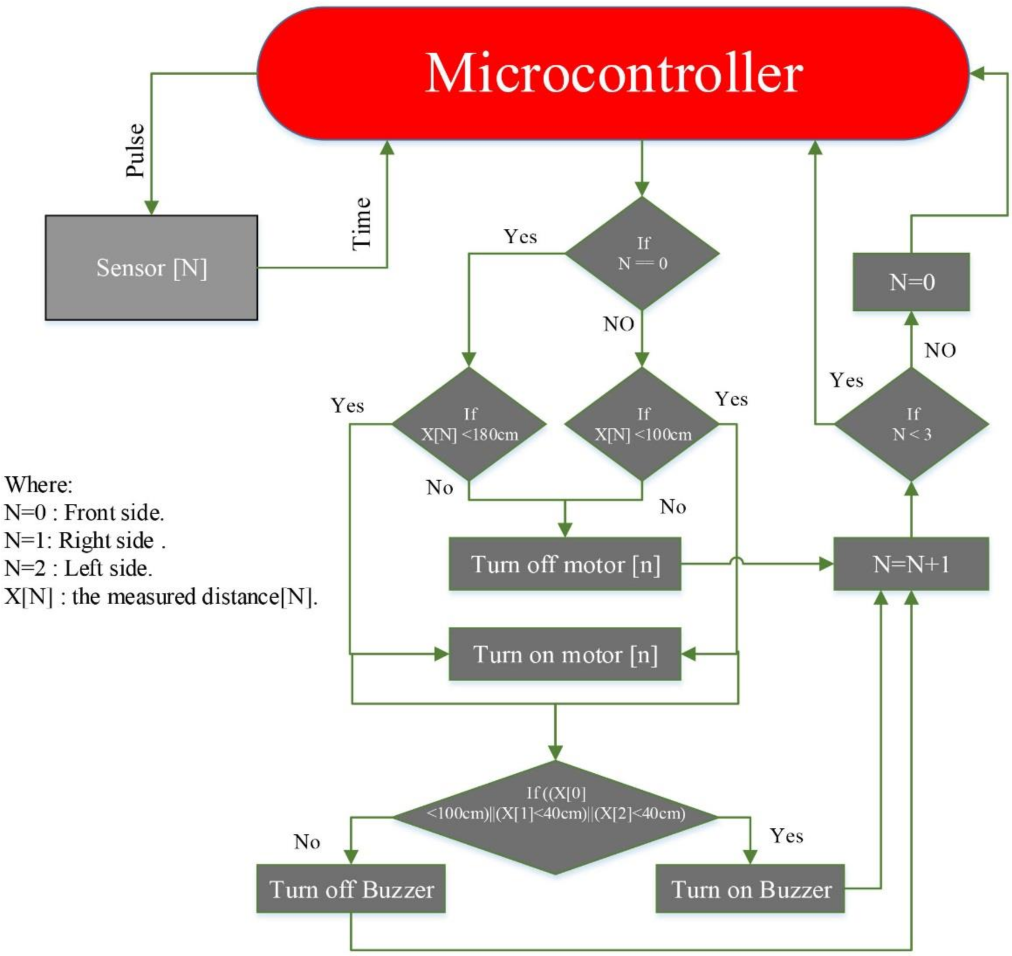

Figure 4.2.1.2.1: Shows the Head-Mounted Navigation Sub-System Flowchart.

4.2.1.3 Functions List

4.2.1.3.1 Main Function

In main function the input pins and output pins are used throughout the program is determined, the initial value for all pins are checked to have zero value. Moreover, time interval for each sensor was determined and stored in an array called pingtimer by using command called "millis" this command evaluates the time from the moment that the Arduino turned on till the command-position, delay between each sensor (33milliseconds) also is taken into account to avoid any intersection between any echoes.

4.2.1.3.2 Loop Function

Here the program will go into a for loop to restoring the new time interval for each sensor as happened in main function to achieve the continuity of reading values and to call the echo-check function after each trigger to store each distance in cm for each related sensor in array. In addition to that, It is checked if one cycle is done for all sensors, then it will go to the sequences function to determine what should be the response according to the value of current distances, after completing one cycle it is adjusted the old distances to zero to start new round with new values, but the time will be cumulative as real time.

4.2.1.3.3 Echo-Check Function

The Echo-check function is used to check the echo pin for each sensor after sending the trigger signal to save it in the distance array and send it later to consequences function.

4.2.1.3.4 Consequences Function

After completing one cycle the program will go to this function to take the suitable procedures according the distances that were stored by the echo-check function. Here Pulse Width Modulation (PWM) is used to make sure that the vibrating motor is related inversely with the distance to help the user in estimating the distance and take the appropriate action.

Now each sensor-distance will be checked, according to the front sensor the range is 100cm-180cm, so that when the distance is 180cm the motor will start working softly as the distance decreases the motor vibration increases till the distance reaches 100cm, at this point the motor will have maximum vibration and a buzzer will be working to make the user stop completely to avoid the collision, 100cm is chosen to protect the user's hand that will be extended to hold the Hand-Mounted Sub-System, while the 180cm is chosen because it is found good enough to avoid the collision of any object and to give the user the enough time to make an action.

For the right/left sensor the range is 40cm-100cm, so that when the distance is 100cm the motor will start working softly as the distance decreases the motor vibration increases till the distance reaches 40cm, at this point the motor will have maximum vibration and a buzzer will be working to make the user stop completely to avoid the collision, 40cm and

100cm are chosen because they are found good enough to avoid the collision of any object and to give the user the enough time to make an action.

4.2.2 Hand-Mounted Tactile Sensor Sub-System

4.2.2.1 Initialization

At the beginning of the program needed variables that will be used throughout the program are defined to give them a place in memory, so that they could be reached easily. Moreover, special pins are given special names, for example, echo pin was labeled as A4.

4.2.2.2 Flowchart

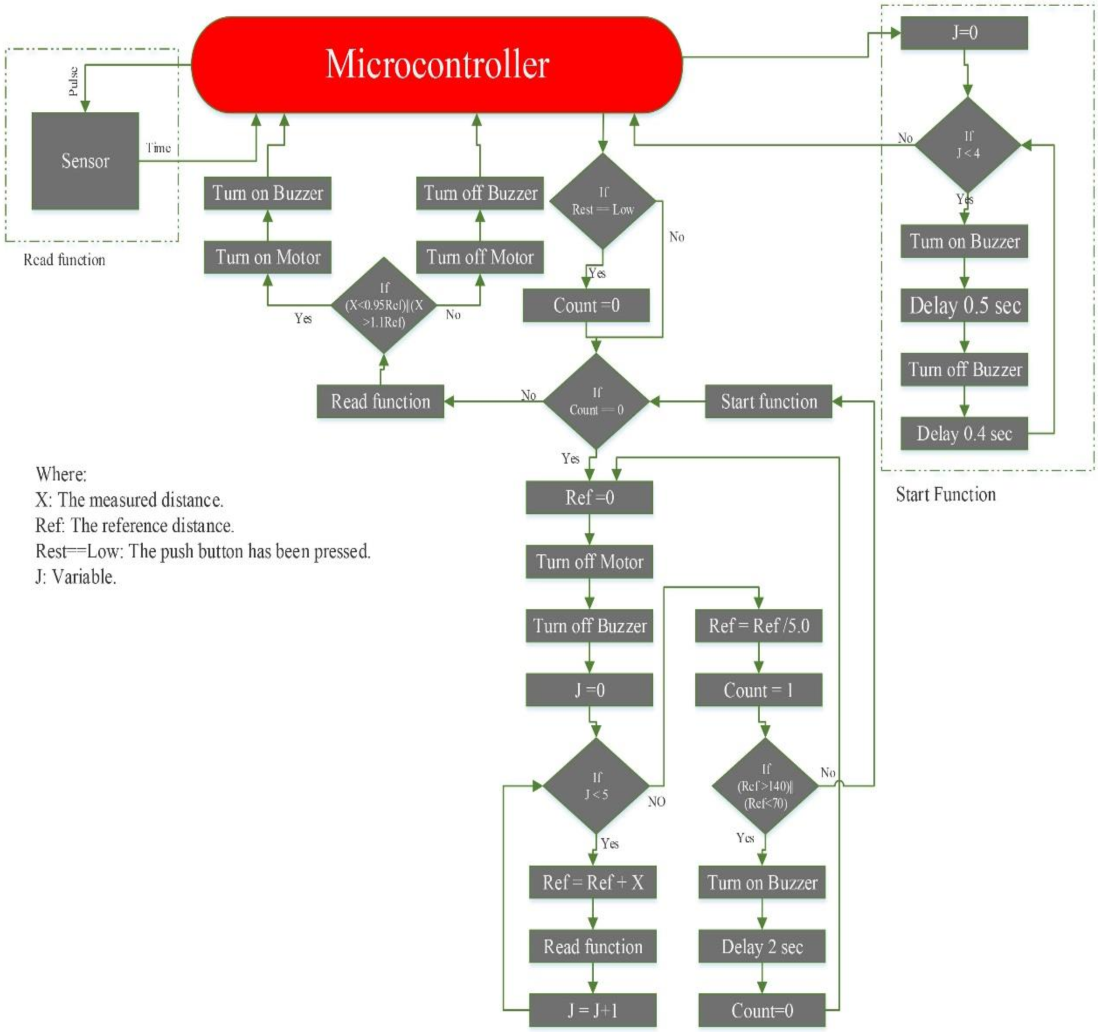

Figure 4.2.2.2.1: Shows the Hand-Mounted Tactile Sensor Sub-System Flowchart.

4.2.2.3 Functions List

4.2.2.3.1 Main Function

In main function the input pins and output pins are used throughout the program are determined.

4.2.2.3.2 Loop Function

This function will be repeated to maintain the continuity of the use. Obviously, at the beginning of the use the user will point the tactile sensor toward specific direction to scan the below-eye obstacles, but the height of the sensor is changeable from user or situation to another, so that a reference value should be taken before the use to notice any change according to it and make sure that the user is in safe. This reference value is determined in this function by taking five reads between each one 50ms, after that an average value will be determined by dividing the sum of reads by 5 to be the reference value.

The reference value will be checked because there is a probability that the user is in danger or the user does not hold the tactile sensor in the right way at the beginning of the use, to overcome that an if clause statement was installed after computing the average value to check it, so that if the reference value is within 70cm to 140cm (those numbers are chosen after experiments and studies taking the normal human being tall into consideration) the program will go to the start function to give the user the four beeps that indicate the user to start walking. Otherwise, continuous beep (two seconds period) will be activated to tell the user that there is something wrong either wrong use or dangerous area, after that the stage of computing the reference value will be repeated till reaching reasonable reference value.

Additionally, a push button is added to let the user change the reference value, for example, if the user wants to change the position of his/her hand then the reference value will be changed and the system will think there is a danger, to overcome that the user can click the push button after changing the positon of his/her hand to compute a new reasonable reference value and estimating the dangers according to it.

As is said the reference value is changeable, because of that the danger zone should be related to the reference value, and it is determined as any distance is larger than 107% or less than 93% of the reference value, the motor will vibrate with maximum value and the buzzer will beep immediately to tell the user that there is a real, close danger surrounds you and you have to change that way. Percentages 107% and 93% is chosen carefully to indicate small changes like downstairs, upstairs, chair, hole, boot and small rocket, for example, if the reference value was 100cm then the danger zone is less than 93cm and larger than 107cm, than means the sub-system will give you warning signal if it indicates any change with more than 7cm.

4.2.2.3.3 Read Function

Here, the ultrasonic rangefinder will be activated by sending a pulse to the trigger pin, then a function that exist in Arduino labeled as PulseIn will read the value from the echo pin and convert the duration time to distance as mentioned in equation 4.2.1.1.1, after that the value will be saved in a variable called CM that will be checked later in the loop function.

4.2.2.3.4 Start Function

The Start function will give the user indicator which is four discrete beeps at the beginning of the usage when the situation is safe, no below-eye level obstacles surround the user and the reference value for the tactile sensor is reasonable.

CHAPTER 5

Results and Discussion

Chapter 5: Results and Discussion

5.1 Speed of Execution

The Bat Hat can detect objects quickly because it is divided to two separated subsystems each one works independently from the other, according to the head-mounted navigation sub-system each rangefinder from the three sensors are given 33ms period to turn on, detect the closest object in its field of view, and turn off, theoretically, it takes 132ms for all rangefinders to make a complete cycle, so that, in one second this sub-system can make 7.5 cycles, which is a fast-speed detection, while the hand-mounted tactile sub-system takes only 33ms after computing the reference value to make a complete cycle because it contains only one rangefinder, that means 30 cycles per second which is ultra-fast detection.

Moreover, the hat is able to detect an obstacle and alert its user to the impediment fast enough to allow him or her to avoid hitting the obstacle, especially if this person is moving cautiously, as a person with a disability would tend to do.

While using this device, the user is still able to quickly detect and avoid nearby obstacles while walking indoors, also the user can estimate the distance apart of an object because this device is supported with PWM that states the level of the vibration increases as the distance between the user and obstacle decreases.

5.2 Accuracy

The ultrasonic rangefinders can detect objects with 3mm resolution between 0 to 4 meters, according to the HC - SR04 datasheet **[16]**. While testing, it is found that the rangefinders struggled and has error values to detect objects past 3 meters. However, since this device is aimed in general for indoor use, 1m to 1.8 m meters is more than enough range to detect nearby obstacles. It also is found that the rangefinders could detect objects with about 2cm resolution. This was especially applicable in this tactile sensor as it allowed the sensor to detect small changes in ranges, which in turn allowed it to detect small objects.

Each rangefinder has field of view of about 15 degrees **[16]**, allowing for a total field of view of 45 degrees for the navigation system that mounted on the head, but the hand-mounted system field of view is controlled by the user's hand and it has range from 15-180 degrees depending on the user's hand that will scan for objects. In software, the threshold is different depending on the sensor, for example, for the front sensor is 180cm while it is 100cm for the right and left sensors, while the threshold for the tactile sensor is the reference value because as is mentioned before it is changeable from user or situation to another, all the thresholds are less than the max distance the rangefinders can detect.

All numbers, ranges and distances mentioned in the section 4.2 have been taken after studies and experiments to guarantee the accuracy of the device, also it can be changed easily for special use. Moreover, the ultrasonic detects a value less than 10cm and larger than 500cm when the distance between the user and an obstacle is more than 500cm, so that it is decided to clip any value above 500cm to avoid errors and confusing results.

One of the main issues was the simultaneous use and interfere of all ultrasonic rangefinders that can affect the accuracy badly. Semaphores are used to ensure that the rangefinders are ranging sequentially such that they do not interfere with each other (e.g. one rangefinder receiving another rangefinder’s reflected pulse). Delays are used to ensure that the rangefinders have sufficient time, also each sensor has its own fixed field of view that makes the overlapping between each other is impossible.

5.3 User Evaluation

The Bat Hat performed exceedingly well during tests when evaluated by our classmates. All users found the device to be very intuitive. Most were able to use it with little to no instructions, suggesting that the interpolated strengths of the pulsing motors were very natural indicators of nearby obstacles and their proximity to the user.

It is found that most users were able to confidently walk around indoor environments with their eyes closed while avoiding most obstacles. The head-mounted sensors allowed the user to detect walls easily, while the hand-mounted tactile sensor was responsive and sensitive enough to enable the user to sense smaller obstacles below eye level that the user could have collided with. In Figure 5 below, users can be seen detecting and avoiding low level obstacles. In Figure 5.3.1 below, users can be seen detecting and avoiding low level obstacles. In Figure 5.3.1 below, user can be seen detecting and avoiding low level obstacles.

Figure 5.3.1: Shows How The User Can Detect And Avoid Obstacles.

5.4 Safety

Because this system might ultimately be used by a person with a disability, safety is of the utmost priority. Safety is enforced in the design by ensuring that all circuitry was as compact as possible and that all batteries and electrical connections were well separated so there would not be an issue with an electrical short.

One of the main features of this device is its separated and integrated tow sub-systems that work independently without any wire connected between them to achieve the same goal which is the safety of the user. This provides easy wearing and protect the user from sticking with them.

Additionally, the angle of the tactile sensor is chosen carefully after a lot of experiments to get minimum percentage of error, it was found that as the angle is close to 90 degree with the ground it will be more accurate because the trigger signal will reflect from the ground directly to the echo pin and get the accurate distance, but if the angle is less than 80 degree for example the trigger signal could reflect to other thing and the echo pin receives nothing, so that wrong results and the user will be in danger, to guarantee the safety of the user the tactile sensor was fixed with the dorsum of the hand to be always perpendicular with the ground regardless of the hand's position either it is parallel with ground or with an angle less than 180 degree.

One of the main safety issues was the reference, this value is determined by taking five reads between each one 50ms, after that an average value will be determined by dividing the sum of reads by 5 to be the reference value with minimum error. Then, the reference value will be checked because there is a probability that the user is in danger or the user does not hold the tactile sensor in the right way at the beginning of the use, to overcome that an if clause statement was installed after computing the average value to check it, so that if the reference value is within 70cm to 140cm the program will give the user the four beeps that indicate the user to start walking. Otherwise, continuous beep (two seconds period) will be activated to tell the user that there is something wrong either wrong use or dangerous area, after that the stage of computing the reference value will be repeated till reaching reasonable reference value. Additionally, the user can click on a specific push button after changing the positon of his/her hand to compute a new reasonable reference value and estimating the dangers according to it because as it is said the danger zone is related to the reference value because it is changeable.

5.5 Usability

This device is designed primarily for visually impaired individuals, it can be used by sighted individuals in other settings. For example, this device can be used in environments where visibility is limited or non-existent. Also, this device provides an advantage of being usable in noisy environments where such conventional echolocation techniques cannot be used.

The headpiece is adjustable, as is the hand piece. This allows for users with differently sized heads and hands to use this device comfortably. The software does an initial calibration for a distance threshold for the virtual cane in addition to push button that let the user to change the reference value at any time. This allows the device to be tailored for people of different heights.

CHAPTER 6

Conclusion and Recommendation

Chapter 6: Conclusion and Recommendation

6.1 Summary

Overall, this finished project (see figures 6.1.1 and 6.1.2) met all the expectations and more. It was stated in the proposal to design a hat and small tactile that eases the daily life of people, especially to those who have disability to get around and understand their surrounding easily by feeding them with indicators which tell them to turn left, right or even if there is anything in their way. Consequently, that will increase the ability to that group to join life with high self-confidence, and also it will increase their capacity in all levels.

Figure 6.1.1: Shows the Head-Mounted Navigation Sub-System.

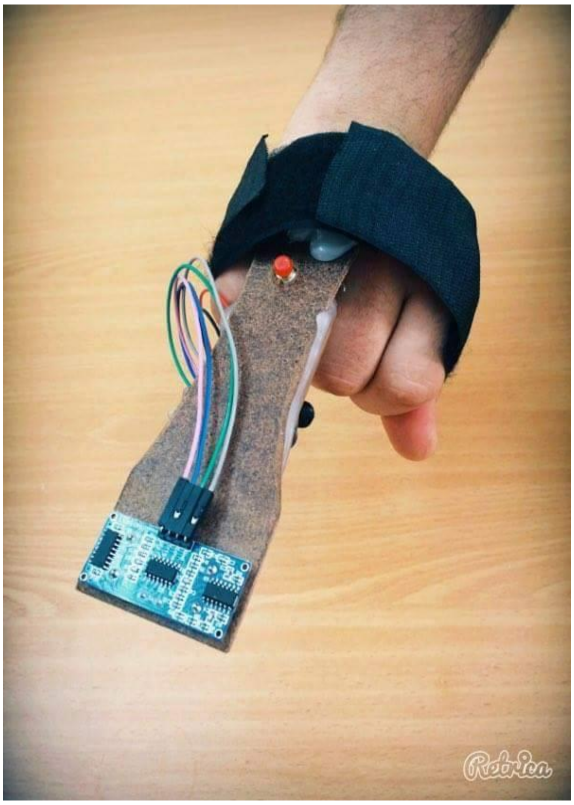

Figure 6.1.2: Shows the Hand-Mounted Tactile Sensor Sub-System.

As a result, a device with two main wearable sub-systems are designed and implemented successfully with basic elements and cheap price, so that poor people who forms the majority of the visually impaired people can buy it and wear it to enhance their daily life. Moreover, the device has many features includes its ability to detect below eye-level obstacles that no previous device has, also the device has the lowest price among all the previous devices that makes it acceptable, and can be used in noisy environment because it uses haptic feedback in addition to its ability to detect obstacles in all direction, all of that make the system reliable and functional device.

The first sub-system is the well-designed head-mounted navigation sub-system that consists of three ultrasonic rangefinders, Arduino UNO and three vibrating motor discs in addition to the buzzer that will send warning signal when the object is very close to the user to increase the awareness. The head-mounted system instructs the user to turn left, right or even indicates if there is something in front of the user using one of the three motors that are mounted on the three sides of the user's head. The rate at which the motors pulse is proportional to the distance of the obstacle from the user -- the closer the object, the more rapid the pulses.

The second sub-system is the stylish hand-mounted tactile sensor that consists of one ultrasonic rangefinder, Arduino NANO and one motor that the user can wear on his or her hand. The tactile sensor allows the user to "scan" for obstacles below eye-level (typically out of the range of the head-mounted sensors) by sweeping his or her hand laterally, similar to how one would use an assistive cane.

6.2 Cost Details and Economical Dimensions

One of the main concerns was the price of the product as stated in the existing problems section "Globally, an estimated 285 million people were estimated to be visually impaired, 39 million were blind and 246 have low vision **[1].** In addition to that, about 90% of the world's visually impaired live in low-income settings **[1].** As a result, this fact forms the motivation to build a clever, small device to help them with a cost considered too cheap related to its valuable function." Clearly, large numbers of poor people are involved so it was a challenge to design a device that is reliable, functional and cheap.

The following table shows all the elements and their related cost:

Part Number	**Vendor**	**Quantity**	**Price/each**	**Total Cost**
Vibrating Mini Motor Disc (Part No. 1201)	Ali Express	4	$1.31	$5.24
Large Solder Board	Ali Express	1	$0.5	$0.5
2N3904 NPN BJT	Ali Express	4	$0.5	$2
Resistors	Ali Express	5	$0.2	$1.00
9V Battery Holder	Ali Express	1	$1	$1.00
9V Battery	Ali Express	1	$2	$2.00
Wire	Ali Express	1	$1	$1.00

HC-SR04 Ultrasonic Wave	Ali Express	5	$0.9	$4.5
Arduino UNO	Ali Express	1	$2.65	$2.65
Arduino NANO	Ali Express	1	$1.74	$1.74
Total cost				**$22.00**

Table 6.2.1: Shows The Cost Of All Elements.

Obviously, the price of the product is too cheap related to its function, many procedures were taken into consideration either in choosing the suitable type of elements or in designing the smart design of the product to get cheap price and reliable product. The low price does not contradict with the quality of the device that makes the device high quality product and it could be commercial product in the future.

6.3 Future Work

With additional time and resources, this device could be further developed for more ergonomic and practical everyday use. For example, it could using other ultrasonic rangefinders or even building our own rangefinder. Replacing the current rangefinders could allow for faster response and better resolution. This replacement could also help in explore how to make the sequential ranging of our sensors more time and power efficient.

It had also planned on using two more rangefinders on the knee of the user for the detection of stairs, tables, chairs and ramps as an addition protection because the hand sub-system already does that, but the time wasn't enough to make tests and try that idea.

It would like to create Android application with headphones that will be used to tell the user the real measured distances and notify the user about the direction that the user should take.

Finally, it is decided to improve the device and increase its safety level by using GPS and GSM that will be used to send a message containing the position and the place of the user to special mobile numbers when the user in real danger and needs immediate help.

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